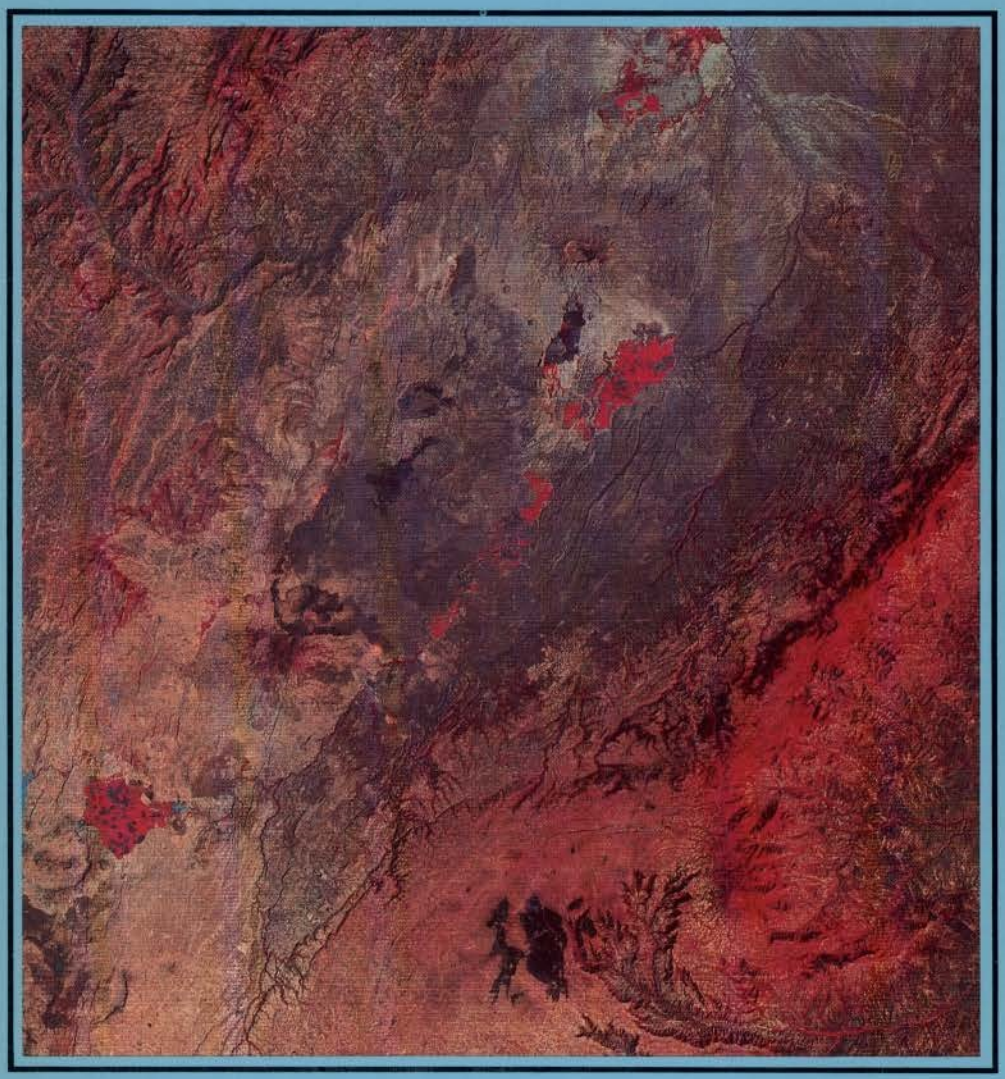
IDRC - 174e

REMOTE SENSING AND DEVELOPMENT

Report on IDRC-supported projects in the Sudan, Bolivia, Tanzania, Bangladesh, and Mali



Robert LeBlond

The International Development Research Centre is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activity is concentrated in five sectors: agriculture, food and nutrition sciences; health sciences; information sciences; social sciences; and communications. IDRC is financed solely by the Parliament of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters are in Ottawa, Canada. Regional offices are located in Africa, Asia, Latin America, and the Middle East.

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Contents

Foreword

Although the International Development Research Centre has devoted only a small fraction of its budget to the field of cartography, it has maintained interest, through its Information Sciences Division, for an entire decade. In 1971, when the Division began operations, it initially concentrated its resources on bibliographic information networks and specialized information centres whose products could be useful for economic and social development in the Third World. But it quickly realized that maps represent an extremely effective medium for presenting large amounts of information in a form that aids the user to retrieve immediately the components that respond to his or her need. And, compared with documents and computers, maps are a cheap medium for transmitting information.

However, the collection of information to be included on a map may be very expensive, particularly when the data cannot be recovered from existing sources and must be produced through ground or aerial surveys. IDRC's resources certainly did not permit it to fund such surveys, and we in the Information Sciences Division looked for other ways to help countries of the Third World obtain maps for development purposes. The first, rather tentative, efforts were started in 1972, essentially for the production of maps from data that had already been recorded in other forms.

In 1973, there came the catastrophic drought of the Sahel. The eyes of all development-aid organizations were drawn to this region of Africa, and each sought to find ways to help relieve the situation and to help develop plans to cope with similar disasters in the future. It became clear that a method for speedy mapping of a changing environment would greatly assist decision-making.

Robert LeBlond was appointed program officer for cartography in October 1973, and, for about a year, he studied various possibilities and consulted with agencies that had experience in the mapping of vast territories. It was decided that IDRC should not become involved in topographic mapping but should devote its limited resources to the type of thematic mapping that would support development programs: themes

such as vegetative cover, land use, hydrology, mineral resources, etc. The question was whether such maps could be prepared without expensive investments in aerial or ground surveys.

At about this time, the United States began to make available the data it had been collecting from its earth resources technology satellites (ERTS, later known as Landsat). Typically, an image covering an area of 185 km × 185 km could be obtained for about US $10. This was fantastically cheap, but the ERTS images needed considerable interpretation before maps could be drawn, and fieldwork was needed for "ground-truthing." Also, cartographers in the developing countries would need to be trained in the techniques, and multidisciplinary teams would need to be put in place if the countries were to be well served. Nevertheless, the production of maps from ERTS data promised to be much less expensive than production from ground or aerial surveys.

In the second half of 1974 and through 1975, Mr LeBlond identified the five projects that are described in this report. Each represents a different experience in "technology transfer," but all represent tests of the feasibility of applying satellite data for the production of thematic maps of importance to development. The results cannot be said to be uniformly successful, but they are sufficiently promising to confirm the original hypothesis: the technique is applicable to developing countries and offers them a low-cost and speedy route to obtaining the thematic maps they need. Perhaps, we did not sufficiently appreciate the need for a strong infrastructure to support cartographic groups using remote-sensing data, and perhaps we were too optimistic in believing that the technology could be carried immediately into national institutions of the poorer countries. But there were no technical roadblocks. As yet, IDRC has not supported any further projects of the type described in this report, but it has made grants to two regional institutions in Africa that attempt to act as "resource centres" for the national authorities in particular countries. Perhaps such centres can fill the gap until such time as adequate infrastructure is built up in the national institutions.

This report is published to share, with personnel working at other institutions, the results of the IDRC experience. The Information Sciences Division continues to devote a small budget to the cartographic program, and I invite interested groups who wish to consult on the matter to contact Robert LeBlond.

John E. Woolston
Director
Information Sciences Division

Introduction

The purpose of this report is to provide information concerning a series of projects dealing with the applications of remote sensing in five developing countries, which were funded by the International Development Research Centre (IDRC) between 1974 and 1979. The practical aim of the projects — in the Sudan, Bolivia, Tanzania, Bangladesh, and Mali — was to provide maps of the natural resources of specific areas in each of these countries as a basis for development and improvement in the areas. The projects were innovative in that they used information-gathering and processing techniques that were new, made available through remote sensing.

IDRC's interest in this field of applied research was aroused when the first images of the earth resources technology satellites (ERTS), later renamed Landsat, were made available in 1972. The National Aeronautics and Space Administration (NASA) in the United States had launched a special program, inviting interested researchers throughout the world to take advantage of this information technology for their various projects, and nearly 60 research activities in developing countries had been successfully completed as early as 1973 under this international program.

At the time, NASA was providing Landsat images and information free of charge to researchers who had submitted a small research project on the applications of remote sensing. This formula rapidly showed how the developing countries could benefit from this new unparalleled type of information gathering. However, the countries of the developing world were not able to profit as much as was desired because of insufficient trained personnel and inadequate work methods.

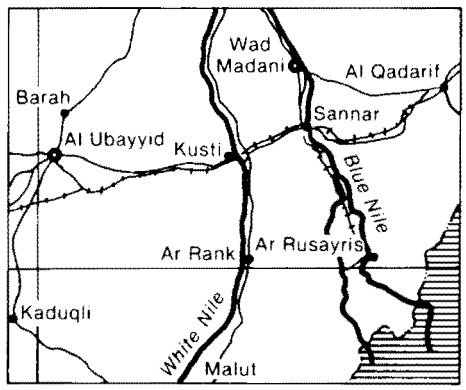
These observations encouraged the IDRC to conduct a more active study through its Information Sciences Division on the manner in which useful assistance in this field of research could best be provided. A preliminary survey of the institutions, programs, and researchers was undertaken in February 1974. IDRC staff needed not only to identify the type of human resources and institutional structures that would be required but also to determine the types of research that would be useful as well as feasible financially.

This preliminary phase made it possible for the staff to develop working contacts with a few organizations, such as the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the US Agency for International Development (AID), that were already involved in this field. Other contacts were needed for logistic support in terms of training and expertise for future projects. Two problems severely restricted the possibilities for projects: the limited number of remote-sensing consultants who were familiar with developing countries and the lack of the structures required on site to undertake such research.

Beginning in the summer of 1974, modest amounts of money were allocated for missions and activities considered useful for program planning; the activities involved a few scientists as well as a number of research groups. For example, IDRC provided funds for a UN regional seminar on applications of remote sensing to geodesy and mapping. This seminar was held in November 1974 in Sao José dos Campos, Brazil. By the end of 1974, the Centre had decided to support a program of five national projects, preferably concentrated in Africa because of the particularly critical nature of the needs in that region. A standard project was then developed as a guide on what IDRC could accept. In December, began the process of obtaining approval and implementing the projects selected for the series.

Preliminary studies were relatively concentrated, and all the projects were set in motion between October 1974 and May 1975. The activities for which the IDRC was responsible in the programs planned for the Sudan, Bolivia, Tanzania, Bangladesh, and Mali were conducted during a period extending to 1979. This report covers each of the projects and concludes with a few general comments to complement this information.

Sudan



The coordinates of the zone studied in Sudan were 12°15′–13°45′N and 30°–31°30′E. The project was the largest of this series, launched just after the disastrous drought in the Sahel in 1973. It was intended to contribute to the testing and use of new techniques for more accurately determining the zones most severely affected by desertification. The research program, involving a test zone of 60 000 km², located at the boundary of the provinces of Kordofan and White Nile, aimed to produce:

- Thematic maps (to a scale of 1 : 250 000) of surface-water hydrology; geomorphology and soils; vegetation; and soil use;
- Thematic maps (to a scale of 1 : 25 000) from digital processing for surface-water hydrology; soils and erosion; vegetation; and soil use in specific sites.

Before the IDRC project in the Sudan, two advisers from FAO (C.W. Mitchell and M.F. Baumgardner) had carried out some research on the applications of remote sensing in this region under an extensive FAO program entitled "Savannah Development." Their work aroused considerable interest on the part of the Sudanese government, which expressed the desire to establish a local unit for remote-sensing research. This unit would carry out more intensive activities of the same type, and the results would be applied to regional development.

The agency designated for this purpose, hence the project team, was the Soil Conservation, Land Use and Water Programming Administration, part of the Ministry of Agriculture, Food and Natural Resources of the Sudan. This multidisciplinary team set to work in the autumn of 1975, and a preliminary study was carried out in the Kordofan zone around El Obeid; the project adviser, M.F. Baumgardner of Purdue University's Laboratory

of Applications in Remote Sensing (LARS) in the USA, accompanied the mission. The last part of 1975 was devoted to gathering and studying complementary documentation (aerial photographs, topographical maps, reports, etc.) on this zone.

In January 1976, the research team, consisting at the time of Hassan El Sheikh, Yahia M. Bushara, Yousif Yagoub, El Mardi Ahmed, Khalid Ahmed Khalid, and Abdel Rahim Abdel Aziz, undertook 3 months' training at LARS. All the practical work during the period was directly applicable to the Sudan project zone. In April 1976, a series of visits to institutions was organized for the group of trainees to foster professional contacts and help them to become familiar with other institutions specializing or interested in remote sensing, such as the Canada Centre for Remote Sensing and the Earth Resources Observations Systems (EROS) Data Centre, Sioux Falls (USA).

The next phase of the project began in the fall of 1976 with a second field mission by the team, the group of Sudanese researchers again being accompanied by Baumgardner to review the research results obtained in the laboratory during the training session.

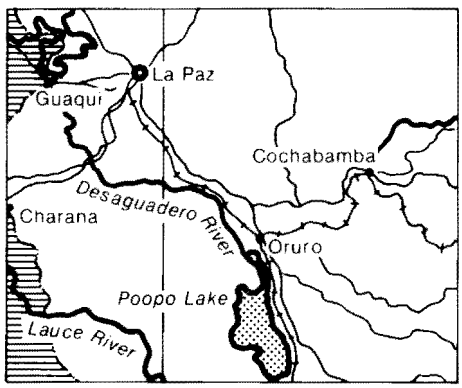
The second year of the project, 1977, was devoted to two main tasks:

- Installing the remote-sensing unit, for which equipment such as a transferscope, a duplicator, and a trinoscope had been provided; and

- Completing the work.

During training, one coloured map (scale, 1 : 250 000) and several computer-generated thematic maps (scales, 1 : 25 000 and 1 : 50 000) were produced, but the production of other maps to a scale of 1 : 250 000 was delayed until after IDRC funding ceased. In the meantime (1978), IDRC published a brief report of the project (IDRC-TS9e), a step that proved useful for the Sudan project as well as the others in the group.

Bolivia



In 1974, the Bolivian government was planning to build a dam in the Desaguadero valley and needed up-to-date maps of natural resources in the area. A study zone (16°40′–18°25′S and 67°15′–69°20′W) was, thus, set out in this region. Located south of the capital city, the area is primarily part of the Bolivian Altiplano where the average altitude is 4000 m and the climate, cool and rather dry. The objectives of the project were:

- To compile — with digital-processing techniques developed for Landsat data — a series of thematic maps on geology, soils, and soil use; and
- To train a basic team including a geologist, an agronomist, and a statistician in this field of application.

Bolivia's interest in remote sensing and applied research in this field dated back to 1972 when the "Programa del Satelite Tecnológico de Recursos Naturales ERTS" (ERTS program) was launched by GEOBOL, the Bolivian geological survey. C.E. Brockmann, who has since played an outstanding role in this scientific field, had involved the IDRC in this project in the latter part of 1974. This project was unique in that the recipient institution was able to take charge of local arrangements and even arrangements for consultations and training abroad. This quality of self-sufficiency expedited IDRC involvement and permitted project activities to begin in mid-1975.

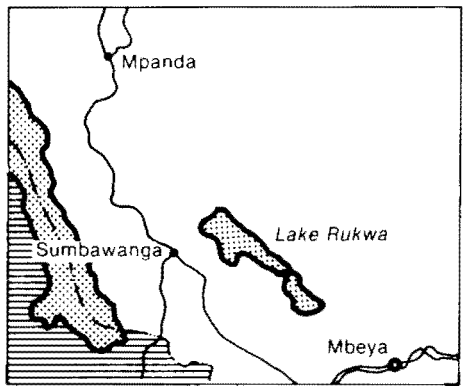
Preliminary field studies in the Desaguadero valley, with input from two advisers from Purdue University's LARS, were conducted until almost the end of 1975. The next year, a small team of Bolivian scientists (Isaac Ugarte, René Valenzuela, and Moisés Urena) completed 3 months of training and practical work at LARS.

Field checks of the maps produced with the digital-processing

techniques (LARSYS-III programing) were carried out toward the end of 1976, and corroboration of these results made it possible to establish a methodology suited to Bolivian requirements and resources.

In early 1978, the results, in the form of an atlas entitled *Area Desaguadero, Procesamiento Digital de Datos Multispectrales*, were published. It is a remarkable work and should be of interest, from a methodological point of view, to anyone considering applied research in remote sensing in Bolivia or other developing countries.

Tanzania



The main purpose of the project in Tanzania was to evaluate the natural resources of the Rukwa region (5°–9°S and 30°30′–33°E) in the East African Rift and bordered by Lake Tanganyika. This vast region of about 68 000 km² includes the two districts of Mpanda and Sumbawanga. In 1974, the Government of Tanzania had entrusted the Bureau of Resource Assessment and Land Use Planning (BRALUP), University of Dar es Salaam, with preparing an integrated development plan for this region.

As such a task seemed to require considerable staff and time, it was decided that a project closely related to this program and based on the applications of remote sensing would be set up. The aim was to obtain the desired results more quickly if possible. BRALUP was able to launch this project with IDRC support during the spring of 1976. The main objectives were to provide:

- Survey maps of natural resources (scale of 1 : 250 000) for hydrology, soils and vegetation, and soil use;
- A training program in remote-sensing techniques; and
- Appropriate equipment.

The project was started in the summer of 1976; the first field group mission included Roger Pitblado of Laurentian University in Canada as adviser. Another scientist, Bruce King, of the UK Overseas Development Administration, was active in the project undertaken by the team of Tanzanian researchers — Idris Kikula, James Ngana, and Firoz Khurgi.

At the beginning of 1977, this research team began intensive training and practical work in remote sensing at Laurentian University, a program

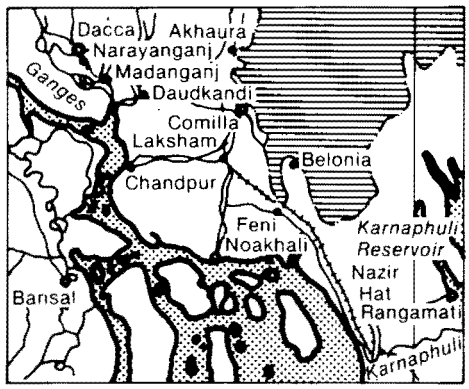
coordinated by Roger Pitblado and Gerald Tapper. This training was followed by a few visits to institutions such as the Canada Centre for Remote Sensing in Ottawa and NASA in Washington, affording the Tanzanian researchers the opportunity to diversify their professional contacts in the field of remote sensing.

Once the group returned to Dar es Salaam in mid-1977, BRALUP had not only a few researchers well-trained in remote sensing but also useful equipment, including a colour-additive viewer, a densitometer, and a duplicator, as well as a stock of work supplies.

Until November 1977, a large part of the project consisted of checking the mapping work in a second field mission, again in the Rukwa region. The results obtained were summarized in a preliminary report near the end of 1978. This was followed by a long delay, resulting from the project orientation review requested by government authorities. This review prompted changes in the research team, as well as in the mapping objectives.

BRALUP completed the report requested and produced two planning maps (scale, 1 : 500 000) outlining the biophysical zones of the districts of Sumbawanga and Mpanda. It also produced a series of maps to a scale of 1 : 1 000 000, covering the agricultural potential of the entire region (for crops such as rice, corn, tobacco, and cotton) as well as the geology, accessibility, and irrigation possibilities.

Bangladesh



Of all the developing countries, few have been struck by as many calamities as has Bangladesh. The precariousness of this situation adds much to the merit of researchers in this country, who, despite the constraints, are doing an admirable and effective job. Their work in the national remote-sensing program (Bangladesh Landsat Program) is a good example, and the activities within it have proved very useful to all regional-planning sectors.

Program officials informed the IDRC during the summer of 1975 of a need for support for remote-sensing research, and the last project in this series was approved (March 1977). However, a few changes from the model of previous projects were introduced during selection of the objectives and execution of the program. Along with the main study (Karnaphuli Reservoir), objectives related to the Ganges basin and the Barind region were included. In addition, this project was carried out in conjunction with two other programs related to the field and funded by FAO and the World Bank, so a few changes were made in the manner of conducting the planned activities.

The project began with a mission to Bangladesh in April 1977 by Professor Richard Protz of the University of Guelph (Department of Land Resource Science), Canada, and his report served as a work plan for subsequent activities. Unfortunately, a follow-up mission by Protz could not take place in November and December 1977, the period that would have been most favourable for fieldwork and would have allowed more information to be acquired for subsequent activities. A decision was made to go on to the training and laboratory work program, and, in April 1978, a team of scientists from Bangladesh (Abu M. Bakr, Abdul Gafoor, Ashraful Islan, and Shafigur Rahman) went to the University of Guelph and then to LARS (Purdue University) for specialized training.

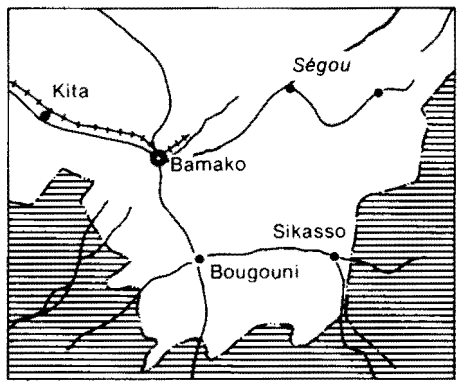
During the training period, a supply of equipment and scientific

material were provided by IDRC, and the acquisitions contributed significantly to the projects funded by other agencies, all of which served to improve the country's remote-sensing laboratory.

On their return to Bangladesh, the team of scientists spent 18 months on research directed toward project objectives, submitting their final report in June 1980. This report, distributed to the Bangladeshi agencies and departments concerned, paved the way for other development projects, particularly with regard to the management of aquaculture, by providing an improved data base.

During the training component of the project, thematic maps to a scale of 1 : 25 000 and 1 : 50 000 were produced by computer. On site, coloured Landsat images were analyzed and were the basis for two maps (scale, 1 : 1 000 000) that outlined hydrology-related features in the Ganges basin.

Mali



For Mali, as for the other countries in the group, remote sensing was considered useful for rapid reconnaissance mapping as a basis for development planning. However, as a tool for development, remote-sensing technology is not sufficient in itself; there must be adequate means to undertake follow-up.

The remote-sensing project in Mali was for the Sikasso region (10°–12°N and 5°–8°W) where economic and geographic conditions showed interesting potential for development. A multidisciplinary project for investigating the region — about 53 000 km² in the southwestern part of the country — was submitted to the IDRC. The main objectives were:

- To train a research team in the techniques of applying remote sensing; and

- To produce thematic maps to scales of 1 : 200 000 and 1 : 500 000 on geology, hydrology, agricultural soil science, soil use, and forest cover.

The development of this project proved laborious. Although Mali had been taking an active interest in the applications of remote sensing since 1972, many other pressing needs constantly delayed implementation of an effective program in this field. It was, therefore, necessary to seek a realistic formula for cooperation.

Mamadou Konaté, then Director general, Direction nationale de la géologie et des mines, Ministère du développement industriel [et du tourisme], played a decisive role in the formulation of the project in 1975, as did Guy Rochon of Laval University (Canada). Rochon undertook an advisory mission to France and Mali in September 1975, and Konaté received support from IDRC for an advisory mission in March 1976. Later, IDRC requested the training and advisory services required for the project

from the Groupement pour le développement de la télédétection aérospatiale (GDTA), France.

Work began early in 1977, with a field mission by the Malian team accompanied by Max Guy of the GDTA. This reconnaissance phase lasted until April, during which time mapping documentation and ancillary data of the study zone were gathered.

From May to September 1977, Mohamed Ag Hamaty, Mamadou Moctar Diallo, Oumar Doumbia, Ousmane Abdou Maiga, and, soon after, Ousmane Camara — researchers assigned to the project — attended the planned training session at GDTA, which combined theoretical courses and practical work on the project zone. The results obtained were checked during field missions between November 1977 and April 1978. These field missions made it possible to correct and occasionally supplement information required to prepare the various maps. A large number of maps were produced to scales of 1 : 500 000 and 1 : 200 000 on geology, hydrography, soil use, forest cover, and agricultural potential in the project zone.

At the end of this project, which was slow to get under way but was the only one in the series that was not held up, it proved desirable to give supplementary training to the Malian team. Thus, the members returned to GDTA from April to June 1978. The senior personnel were engaged for the additional time to complete the work, especially for final publication of results. The summary report prepared for the development of the Sikasso region, like the atlas from the Bolivian project, may prove suitable as a methodological reference — in this case, for more extensive study of natural resources in the Sudan–Sahel zone.

Summary

This brief overview of the five remote-sensing projects (Table 1) supported by IDRC would be incomplete without an overall assessment of the undertaking. The institutional resources available for support of such projects are critical, as are the size of the study zone, the fieldwork, and the techniques for mapping and dissemination of results. IDRC's experience in these areas may be useful to others who fund research in this discipline.

Institutional resources

The roles and the manner of operating of institutions in developing countries vary considerably and depend, among other things, on their functional and professional characteristics. The policies on participation of researchers in projects financed from abroad also vary widely and may strongly influence the results of a project. At first glance, a university department may seem appropriate for remote-sensing research, but, in many developing countries, the teaching loads are heavy and physical resources are often limited. Government departments, or specialized centres associated with them, provide, at times, more productive environments.

In Bolivia and Bangladesh, remote-sensing research centres had already been established when IDRC was first approached for funding, and this ready-made infrastructure made things considerably easier. Tanzania had BRALUP, and, although in 1974 BRALUP was not laying any claim to expertise in remote sensing, the country was considered ideal for a program in this field because of its top-rate scientific personnel. In Mali and the Sudan, small government departments took the initiative in this field of research. Despite their commendable efforts, these groups found it difficult to locate work areas suitable for research purposes.

Even in 1975, consultants in the application of remote sensing who

Table 1. Five remote-sensing projects funded by IDRC, 1974–79.

Project	Budget ($1000)	Country	Institution	Research area (10^4 km^2)	Methods	Training institutions	People trained
740135	180	Sudan	Soil Conservation, Land Use and Water Programming Administration	6.0	Remote sensing, digital processing	LARS, Purdue University, USA	6
740136	70	Bolivia	GEOBOL/Programa del Satelite Tecnológico de Recursos Naturales	3.5	Remote sensing, digital processing	LARS, Purdue University, USA	3
750126	106	Tanzania	Bureau of Resource Assessment and Land Use Planning	6.8	Remote sensing, visual analysis	Laurentian University, Canada	3
760063	145	Bangladesh	Bangladesh Landsat Program		Remote sensing, visual analysis, digital processing	Guelph University, Canada; Purdue University, USA	4
760070	180	Mali	Direction nationale de la géologie et des mines	5.3	Remote sensing, visual analysis	GDTA, France	4

were sufficiently specialized in a given field and familiar with developing countries were not easy to find. And, although all the consultants and institutions associated with the execution of these projects fulfilled their obligations with considerable competence and commitment, the results were not consistent. The excellent Purdue University program, which concentrated on the computer processing of remote-sensing data, enabled the Bolivian project to make substantial progress, although it was less successful in providing support needed by the Sudan project.

Project and study zones

There was some confusion about the project zones, which were much more extensive than the areas studied. All the project zones had been chosen because they had been given top priority in planning and development, but the researchers needed to work on smaller areas for sampling purposes. Although the projects were justified because of their contribution to development studies, in future, remote-sensing research should be conducted in small test zones. In addition, it would have been wise to invest more in the production of Landsat-enhanced images, which would have provided detailed information about the project zones. Moreover, work for which local resources were inadequate or hard to come by should have been ruled out.

Fieldwork

The number of days initially scheduled for field study proved to be insufficient for all the projects, although this problem was remedied as work progressed. In the case of the two African projects, the work was seriously hampered by a shortage of serviceable vehicles, and other means of transportation such as aircraft and helicopters should have been used in all the projects. These methods would have been more costly but also much more efficient.

Mapping and dissemination of final results

Producing the maps and reporting the results were the areas where most of the projects suffered serious limitations. Although the Mali project was able to keep to the schedule, considerable delays were common for the other four projects. Because the countries involved had full responsibility for these tasks, IDRC was unable to intervene and remedy this situation.

Similarly, it was not always possible to check results against objectives. There were bound to be a few variations in the theme and

scales, but no one offered explanations about changes made while a project was under way. If more were known about the reasons behind changes, similar problems could be avoided in future projects.

Conclusions

Two events before this report was written enabled IDRC to formulate conclusions regarding the implementation of these projects. The first was a workshop held in Nairobi in March 1978, where the people primarily responsible for these projects compared notes. Although the projects had not all been completed, a good many problems related to applied research in remote sensing had become quite clear.

This workshop was intended to foster consultation for future IDRC action programs; its recommendations stressed:

- The usefulness of remote sensing and the need for continuing applied research;
- The need for setting up a national structure in each country to take full advantage of remote sensing;
- The benefit for developing countries of joining together in regional programs, which serve them more efficiently than national programs; and, finally,
- The wish that better systems of cooperation and communication would generate a greater appreciation of the contribution of remote sensing.

The second event was the internal evaluation of four of the five projects, which took place in the fall of 1979. It emphasized the diversity of the results. It showed that there was clearly a need to seek solutions better adapted to the needs of the developing countries. The needs of the African countries are not comparable with those of other regions in the world. Yet, it is in these countries, which appear to be the most ill-equipped in terms of material resources, that advanced technology such as remote sensing would produce very useful results at reasonable cost. However, even if African countries are given the means to take advantage of remote sensing, a process for transferring and learning the technology must be carefully developed to ensure success.

Appendix: project-related publications

Baseline report for integrated development of Rukwa region (Tanzania). Bureau of Resource Assessment and Land Use Planning, University of Dar es Salaam, 1977. 370 p.

Land resources of the Rukwa region: a reconnaissance assessment. 1: the physical environment; 2: land systems; 3: appendices and maps. R.B. King et al. Bureau of Resource Assessment and Land Use Planning, University of Dar es Salaam, 1979. 531 p.

Méthode d'étude des ressources naturelles par télédétection spatiale: une expérience sur la région de Sikasso, Mali. Ministère du développement industriel et du tourisme, Direction nationale de la géologie et des mines, Bamako, 1978. 85 p.

Procesamiento digital de datos multispectrales: area Desaguadero, proyecto experimental (Bolivia). Ministerio de Mineria y Metalurgia, GEOBOL, La Paz, 1977. 58 p.

Remote Sensing in the Sudan. Ministry of Agriculture, Food and Natural Resources, Sudan. International Development Research Centre, Ottawa, Canada, 1978, IDRC-TS9e. 36 p.

Report on the Bangladesh applied research and training programme in remote sensing. Bangladesh Landsat Programme, Dacca, 1980. 65 p.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